specMACS Observations during EUREC^{4}A

Cloud Droplet Size Distributions (from Observations of Glory and Cloudbow) and Cloudmask

Veronika Pörtge [1] ✉

Tobias Kölling [1], Tobias Zinner [1], Linda Forster [1,2], Felix Gödde [1] and Bernhard Mayer [1]

May 7, 2020

[1]Meteorological Institute, Ludwig-Maximilians-Universität München, Germany

[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

OVERVIEW

How is *specMACS* designed?

- downward measurements; mounted onboard research aircraft *HALO*
- two hyperspectral line cameras (400 nm – 2500 nm) and two 2D polarization cameras

Which products will be derived from the measurements?

- Identify clouds in the observations (cloudmask) ▸ slide 2
  - cloud detection algorithm based on brightness threshold and water vapor (WV) absorption in the shortwave infrared (SWIR) solar spectrum $\rightarrow$ works also if sunglint present
- Retrieve microphysical parameters ▸ slides 3-5
  - (polarized) observations of the backscatter glory and the cloudbow depend on effective radius r_{eff} and width σ of cloud droplet size distribution (CDSD)

Which radiative transfer models are used?

- cloudmask: DISORT (included in the libRadtran package)
- CDSD: MYSTIC (included in the libRadtran package, [Mayer and Kylling, 2005, Emde et al., 2016])

LMU MIM

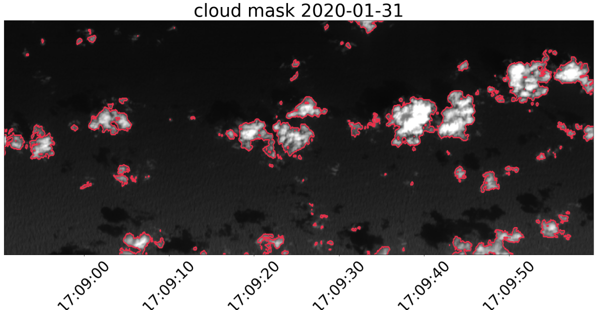
CLOUD MASK [GÖDDE, 2018]

Challenges

- common cloud detection approaches use contrast of bright clouds in front of dark background
- approach fails in the presence of sunglint over ocean (sunglint increases brightness of ocean)

Solution: Use absorption by water vapor!

- absorption by WV in the shortwave infrared solar spectrum (SWIR)
- no cloud → SWIR radiation reflected from ocean's surface → higher WV absorption than radiation reflected at cloud (due to longer path through the atmosphere and higher WV concentrations near surface)



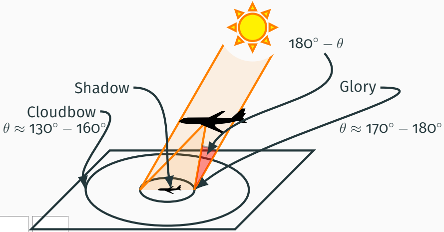
Challenges

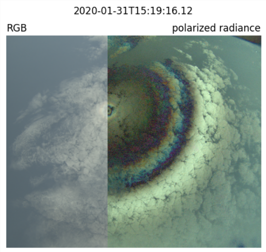
traditional bi-spectral approaches (e.g., Nakajima-King technique)...

- ... retrieve cloud optical thickness and cloud effective radius
- ... suffer from 3D radiative transfer effects (e.g., shadows)
- ... cannot retrieve width of droplet size distribution

Solution: Fit MYSTIC simulations to observations of glory and cloudbow!

Formation: Single scattering by liquid cloud droplets ($\rightarrow$ not affected by 3D effects); scattering angle: θ





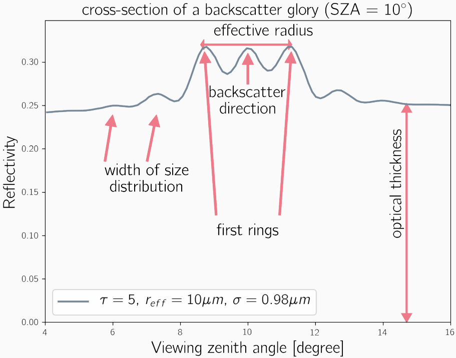
visibility of glory and cloudbow in polarized measurements (right) enhanced due to removal of multiple-scattering background

LMU MIM

RETRIEVAL

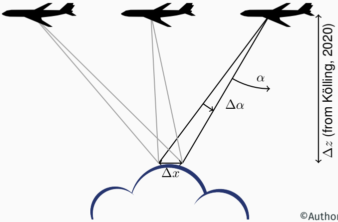
Dependence on cloud droplet size distribution?

- angular radius of glory decreases with effective radius while the radius of the cloudbow increases
- narrow size distribution enhances contrast of the rings (not shown)



Aggregation of observations

- observation of same cloud element in successive images → observation from different angles
- necessary: cloud top height (from [Kölling, 2020])

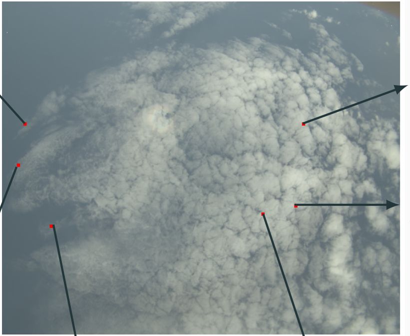


LMU MIM

Results

pre-calculated MYSTIC simulations are fitted to the aggregated observations [Mayer et al., 2004] $\rightarrow$ retrieve r_{eff}, σ with a spatial resolution of about 20 m

selected retrieval results 2020-01-31T15:19:16.12



$r_{\text{eff}} = 4.2\,\mu\text{m}$, $\sigma = 0.6\,\mu\text{m}$

$r_{\text{eff}} = 8.1\,\mu\text{m}$, $\sigma = 1.3\,\mu\text{m}$

$r_{\text{eff}} = 7.8\,\mu\text{m}$, $\sigma = 1.1\,\mu\text{m}$

$r_{\text{eff}} = 7.9\,\mu\text{m}$, $\sigma = 1.7\,\mu\text{m}$

$r_{\text{eff}} = 6.9\,\mu\text{m}$, $\sigma = 2\,\mu\text{m}$

$r_{\text{eff}} = 7.7\,\mu\text{m}$, $\sigma = 1.5\,\mu\text{m}$

Thank you and stay healthy!

Emde, C., Buras-Schnell, R., Kylling, A., Mayer, B., Gasteiger, J., Hamann, U., Kylling, J., Richter, B., Pause, C., Dowling, T., et al. (2016).

The libRadtran software package for radiative transfer calculations (version 2.0. 1).

Geoscientific Model Development, pages 1647–1672.

Gödde, F. (2018).

Detecting clouds in the presence of sunglint: An approach using spectral water vapor absorption.

Master's Thesis.

Kölling, T. (2020).

***Cloud Geometry for Passive Remote Sensing*.**

PhD thesis.

Mayer, B. and Kylling, A. (2005).

The libRadtran software package for radiative transfer calculations-description and examples of use.

Atmospheric Chemistry and Physics, 5(7):1855–1877.

Mayer, B., Schröder, M., Preusker, R., and Schüller, L. (2004).

Remote sensing of water cloud droplet size distributions using the backscatter glory: a case study.

Atmospheric chemistry and physics, 4(5):1255–1263.

LMU MIM